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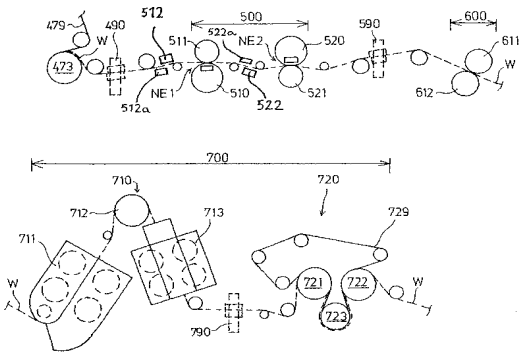
(54) Title: METHOD, PAPER MACHINE AND BASE PAPER FOR THE MANUFACTURE OF LWC PRINTING PAPER COATED ONCE



(57) Abstract: A method, a paper machine and a base paper for the manufacture ofLWC printing paper which is coated once. The paper machine comprises a headbox (100), a gap former (200), a press section (300) which comprises at least one extended nip press, a pre-dryer section (400) in which a web (W) is dried applying at least cylinder drying (R1-R7), a pre-calender (500) in which the web (W) is pre-calendered, at least one portion which is formed of a coating station (600) and an after-dryer section (700) and in which the web (W) is coated on both sides applying a film coating method or a non-contact coating method and dried applying at least contact-free drying (710), an end calender (800) in which the web (W) is calendered, and a reel-up (900) in which the web (W) is reeled. The pre-calender (500) is a calender which is provided with at least one nip (NEl, NE2) and in which both surfaces of the web are in contact with a calendering backup surface having a surface temperature of at least 200 °C, advantageously at least 250 °C, the total length of the nip or nips of the pre-calender is in a range of 15-600 mm, advantageously in a range of 30-600 mm, the linear load of each nip is in a range of 50-500 kN/m, advantageously in a range of 100-400 kN/m, and the moisture content of the web before the first nip of the pre-calender (500) is in a range of 5-20 %, advantageously in a range of 6-15 %.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Method, paper machine and base paper for the manufacture of LWC printing paper coated once

The invention relates to a method for the manufacture of LWC printing paper coated once according to the preamble of claim 1.

The invention also relates to a paper machine for the manufacture of LWC printing paper coated once according to the preamble of claim 22.

Further, the invention relates to a base paper according to the preamble of claim 43.

FI patent application 991096 discloses a method and a paper machine line, in particular for the manufacture of fine paper. By fine paper is meant uncoated or coated fine paper. The basis weight of uncoated fine paper is normally in a range of 40-230 g/m^2 and the basis weight of coated fine paper is in a range of 60-250 g/m^2. The proportion of mechanical pulp in fine paper is generally below 10 % and fillers are added to the stock in an amount of about 15-30 %. Recycled fibres can also be used in the pulp. The paper machine line comprises a short circulation the stock volume of which has been minimized, a headbox, a gap former, a press section comprising at least one extended nip press, a dryer section of which at least a portion is based on impingement drying, a pre-calender, a two-side pre-coater and a dryer section after that, an on-line coating station/stations and an after-dryer section/sections mainly based on contact-free drying after the on-line coating station/stations, an on-line calender in which the linear loads can be regulated separately in each nip, and a reel-up. The pre-calender can be a hard nip calender, a soft calender or an extended nip calender. Relatively low linear loads are used in the pre-calender, for example, below 80 kN/m. Pre-coating can be accomplished by means of a film transfer coating device marketed under the name

SymSizer or OptiSizer. The function of pre-coating is to make the pores in the surface structure of the base paper smaller in a suitable manner in order that the actual surface coating shall remain on the surface and is not absorbed into the structure of the paper. In coating it is possible to use a suitable coating station, for example, a blade coater, a coating device of the jet or spray type, advantageously a coating device marketed under the name OptiCoat Jet. Here, the paper machine in question is thus a paper machine in which coating is accomplished twice.

FI patent 104100 discloses an integrated paper machine. The paper machine comprises, in the running direction of the web, a multi-layer headbox, a gap former having at least one pre-press, a press section having at least one extended nip press, a pre-dryer section in which the web is dried by a high-capacity drying unit, a dryer section comprising at least one drying group that applies single-wire draw, and a surface treatment device for the web. The paper machine has a closed draw at least to the end of the dryer section. The surface treatment device may be formed of a pre-calender, which is provided between a drying cylinder and a roll.

FI patent application 981331 discloses a method and a paper machine for the manufacture of paper. The method and the paper machine are most suitable for the manufacture of glossy and porous paper for colour powder printing. The paper machine comprises a headbox, a wire section, a press section, a dryer section, a coating section, an after-dryer section, a calender, and a reel-up. The headbox and the wire section are designed such that paper is provided with a desired composition layering in the z-direction and that the calender is a calender device that maintains or at least substantially preserves the porosity of the paper web existing before calendering.

In this patent application, by LWC printing paper (Light Weight Coated) which is coated once is meant a printing paper the basis weight of which is in a range of 35-70 g/m^2 and in which the basis weight of the coating is in a range of 2-12 g/m^2/side. Each side of the base paper is coated once. In the arrangements of the

state of the art intended for the manufacture of this kind of printing paper, the base paper is subjected to light pre-calendering after the dryer section before coating. The pre-calendering according to the state of the art is carried out by a one-nip machine calender such that the thermo roll temperature is in a range of 60-100 °C and the linear load is in a range of 10-80 kN/m. Pre-calendering is performed in the state-of-the-art arrangements with low linear loads in order not to lose too much bulk in pre-calendering. This kind of state-of-the-art light pre-calendering provides base paper having a PPS-s10 smoothness in a range of 4-5.7 µm, Cobb-Unger oil absorption in a range of 13-26 g/m^2 and bulk in a range of 1.7-1.9 cm^3/g.

Out of this kind of state-of-the-art base paper it is possible to manufacture LWCO printing paper (Light Weight Coated Offset), i.e. lightly coated offset printing paper using a film coating method or a non-contact coating method. On the other hand, out of this kind of state-of-the-art base paper it is not possible to manufacture LWCR printing paper (Light Weight Coated Rotogravure), i.e. lightly coated rotogravure paper using a film coating method or a non-contact coating method. This is due to the fact that the film coating method as well as the non-contact coating methods do not cover the uneven surface structure of the base paper in single coating, but this uneven surface structure of the base paper is also visible in the surface structure of the coated paper. Therefore, LWCR printing paper manufactured out of state-of-the-art base paper must be made by a blade coating method, whereby the uneven surface structure of the base paper is covered in coating and the finished coated paper attains the surface properties required from LWCR printing paper. The blade coating method in turn requires that the base paper contains at least 40-50 % chemical pulp and that there is hardly any recycled fibres in the base paper. The above-mentioned amount of chemical pulp provides the base paper with the strength required in blade coating. The blade coating method limits the speed of the paper machine in on-line coating to a value of about 1800 m/min.

Since the film coating method is, by a rough estimate, about 5 % more efficient than the blade coating method and since the film coating method does not impose limitations on the speed of the machine in on-line coating, it would be desirable to replace the blade coating method with a film coating method or with a non-contact coating method also in the manufacture of LWCR printing paper. In order that LWCR printing paper might be manufactured by a film coating method or non-contact coating method, the PPS-s10 roughness of the base paper shall be below 3.5 μm and its Cobb-Unger oil absorption shall be below 15 g/m^2. A reduction in roughness and oil absorbency in turn requires more efficient pre-calendering, with the result that the base paper is densified and some bulk is lost. The loss of bulk of the base paper has been thought to also lead to a loss of bulk of equal magnitude in the coated end product and thus, in the opinion of the person skilled in the art, the manufacture of LWCR printing paper has not been possible by using a film coating method or a non-contact coating method.

However, in the invention it has been surprisingly found that the bulk lost in reinforced pre-calendering does not necessarily lead to a corresponding loss of bulk in the end product. By means of the method in accordance with the invention it is possible to manufacture LWC printing paper which is coated once and the bulk of which is at least as good as the bulk of LWC printing paper manufactured according to the state of the art.

The method according to the invention is mainly characterized in what is stated in the characterizing part of claim 1.

The paper machine according to the invention is in turn mainly characterized in what is stated in the characterizing part of claim 22.

The base paper according to the invention is in turn mainly characterized in what is stated in the characterizing part of claim 43.

The arrangement in accordance with the invention employs a film coating method or a non-contact coating method and reinforced pre-calendering. The reinforced pre-calendering in accordance with the invention provides a base paper out of which it is possible to manufacture LWCR printing paper using a film coating method or a non-contact coating method.

The reinforced pre-calendering in accordance with the invention is based on the gradient calendering principle known per se, in which the surfaces of the web are densified and the middle part of the web remains bulky. When a web with a suitable moisture content is brought under pressure in a pre-calendering nip into contact with a hot backup surface, the surface temperature of the web can be raised above the glass transition temperature of fibres, which is dependent on the moisture of the fibres. The intention is to bring the surface of the web into a state in which the plastic deformation of the fibres is permanent. In that connection, the fibres in the surface of the web do not return to their original round shape and position in the treatment stages which take place subsequent to pre-calendering and increase the moisture content of the surface of the web. The relaxation of fibres, i.e. return to the original form, causes non-desirable re-roughening of the web surface.

By the thermal effect of the pre-calender thermo roll, the surface of the web lying against the thermo roll is closed. The pre-calender also improves the smoothness of the surfaces of the web and attaches loose fibres or other stock components to the surface of the web. The pre-calender also makes it possible to correct the two-sidedness associated with the smoothness and oil absorbency of the web. This can be done in a pre-calender provided with two nips by regulation of the moisture content of the web and/or by regulation of the temperatures of the thermo rolls. In each pre-calendering nip, the calendering effect is strongest on the surface of the web lying against the thermo roll. In the first pre-calendering nip, one surface of the web will be against the thermo roll and, in the second pre-calendering nip, the opposite surface of the web will be against the thermo roll. Since the web dries in

the first pre-calendering nip, the calendering effect of the second pre-calendering nip is smaller than that of the first one if the same temperatures are used in the thermo rolls. The calendering effect of the second pre-calendering nip can be enhanced by moisturizing the web between the pre-calendering nips. The calendering effect of the second pre-calendering nip can also be enhanced by using a higher temperature in the second pre-calendering nip than in the first pre-calendering nip. Of course, the magnitude of the linear load used in each pre-calendering nip also has an effect on the calendering efficiency of said nip.

Some bulk is lost in the base paper in the reinforced pre-calendering in accordance with the invention but, surprisingly, the bulk of the end product remains on at least the same level as that of the LWCR printing paper manufactured by the blade coating method in accordance with the state of the art.

One explanation for this phenomenon is that, because of reinforced pre-calendering, end calendering can be made lighter. Thus, the loss of bulk in end calendering remains smaller than in the arrangements of the state of the art.

Another explanation for this phenomenon is probably found in the pulp used in the manufacture of paper. The film coating method or the non-contact coating method used in the arrangement in accordance with the invention makes it possible to drop the proportion of chemical pulp below 30 %. The film coating method and the non-contact coating method do not require the same strength from the base paper as the blade coating method. The proportion of mechanical pulp can in turn be raised to at least 70 %. In addition, recycled fibres can be used in the pulp, in which connection the chemical fibres contained in the recycled fibres are included in the above-mentioned proportion of chemical pulp and the mechanical fibres contained in the recycled fibres are included in the above-mentioned proportion of mechanical pulp. The ability of mechanical pulp fibres to recover their original shape after compression taking place during calendering is considerably better than that of chemical pulp fibres and thus a larger portion of

mechanical pulp helps the bulk of the middle part of the web to be preserved, although the surfaces of the web are densified.

Increasing the proportion of mechanical pulp also improves the formation of the web, i.e. small-scale variation of the basis weight in the base paper decreases. Mechanical pulp, which comprises shorter fibres than chemical pulp, forms less flocs in the forming section, whereby the web becomes more even. This also leads to the fact that the porosity of the surface layers of the web is already reduced in the forming section, with the result that the surfaces of the web become dense.

The light scattering coefficient of the base paper is also improved when the proportion of mechanical pulp is increased because the light scattering coefficient of mechanical pulp is 60 and the light scattering coefficient of chemical pulp is 25. As a result of this, the opacity of the paper produced as the end product is improved.

A reduction in the proportion of chemical pulp also leads to savings in costs because chemical pulp is generally more expensive than mechanical pulp. The use of recycled fibres also makes the pulp less expensive as compared with the traditional pulp used in LWCR printing paper.

A higher than normal moisture content of the web when entering the pre-calender can be made use of in the pre-dryer section preceding the pre-calender. The web simply need not be dried as much in the pre-dryer section, which means that the energy demand of the pre-dryer section is reduced. Pre-calendering also reduces the need for end calendering. End calendering can be accomplished with a smaller number of nips or with lower linear loads. When the two-sidedness possibly found in the web in PPS roughness and Cobb-Unger oil absorption is corrected in the pre-calender, end calendering is facilitated.

By the method in accordance with the invention it is possible to manufacture both LWCO and LWCR printing paper. The greatest advantage is achieved in the manufacture of LWCR printing paper because the state-of-the-art blade coating method can be replaced with a more efficient and less expensive film coating method or non-contact coating method.

In the following, components suitable for the paper machine according to the invention are described with reference to arrangements known per se and disclosed in patent literature or other publications. With these references, said publications are incorporated in this application.

The short circulation process arrangement can be accomplished in the manner described in *WO publication 99/64668* and marketed under the trademark *OptiFeed™*. The mixing of component stocks takes place immediately after the proportioning chests of the component stocks in a closed mixing volume, after which the stock is passed in a closed volume to a headbox. By minimizing the volume of the short circulation and by using an abundance of automation, the time taken by a grade change can be shortened from one hour to a few tens of seconds. From the point of view of the invention, it is also possible to use a traditional stock feed arrangement that is based on a proportioning chest, a machine chest, and a wire pit.

Fillers, fines and additives can be fed into the stock before the headbox or only in the headbox. Here, it is also possible to use a short circulation and/or a headbox that allows layering of additives and/or fillers and/or fines. One stock feed arrangement of this kind is disclosed in *EP patent 651 092*.

As the headbox it is possible to use a single- or multilayer headbox. One multilayer headbox is described in *PCT patent application FI97/00713* and in the paper by *M. Odell: Multilayering, Method or Madness?, XI Valmet Paper Technology Days 1998*. The web can be provided with desired layer structures by

means of a multilayer headbox by feeding the stock in layers between wires. The single- or multilayer headbox can be a dilution headbox, which is marketed under the trademark *OptiFlo*™. In this headbox, the basis weight profile can be regulated by consistency regulation and in it it is possible to affect the fibre orientation by adjusting the profile. A dilution headbox allows a uniform profile to be imparted to the web both in the machine direction and in the cross direction.

From the viewpoint of the invention, it is advantageous that the forming section is based on a gap former, for instance, on a roll gap former, a blade-shoe gap former or a roll blade-shoe gap former. The gap former is preferably provided with loading dewatering elements. In the gap former, a slice jet produced by the headbox is passed between two wires and most of the water is removed between said wires in two directions, thereby producing a symmetric web. *US patent 5,798,024* discloses one advantageous roll blade-shoe gap former applied in the invention. The paper by *L. Verkasalo: Efficient forming at High Speeds, XI Valmet Paper Technology Days 1998* describes one advantageous gap former sold under the trademark *OptiFormer*™. The fibre and filler distribution in the thickness direction of the web can be controlled to some extent by placement and vacuums of the dewatering elements of the gap former. Fillers are often accumulated on the surfaces of the web in the dewatering stages. A gap former allows higher speeds than those allowed by other types of formers and it provides good formation for the web that is being formed. The dewatering blades fitted immediately after a forming roll reduce the layer thickness of the web before loading blades. This in turn has a positive effect on the formation of the web that is being formed. The formation of the web is advantageously below 3.0 g/m^2. The blades can be loaded with a relatively high force because the internal bond strengths of the web that is being formed are not of high significance when coated paper is manufactured. In this kind of gap former, the surface of the web can be closed, so that the penetration of the coating agent into the web is reduced. The good formation, closed surfaces, good symmetry, uniform profile and sufficient

smoothness attained by the gap former create good opportunities for the further treatment of the web.

The press section must have a closed and supported draw through the entire press section in order that it might be run at high speeds, typically over 1800 m/min. The solids content of the web shall be raised in the press section to a value of over 45 %, which is in itself possible in a press section provided with both roll nips and extended nips. A high solids content is required in order that the tensile stress directed at the web between the press section and the dryer section may be minimized. The speed difference of the web between the press section and the dryer section is advantageously below 2 % because the porosity of the web increases with higher differences of draw. Good bulk, a high solids content and a web that is as symmetric as possible are achieved by using a press section provided with one or more double-felted extended-nip presses. *WO publication 99/60202* discloses in one embodiment a press section provided with two separate double-felted extended nips. A press section is marketed under the trademark *OptiPress™* with one of its embodiments comprising two separate extended nips which are both double-felted. This kind of press section provides symmetric dewatering and a web which is symmetric in its surface properties. One of the felts can also be replaced with a transfer belt that does not receive water and transfers the web well. The smoothness of the web and its two-sidedness as well as the absorbency of the web can be controlled by means of transfer belts and press felts.

In the pre-dryer section it is possible to use cylinder drying and/or blowing drying, for example, impingement drying and/or through drying. The upstream end of the pre-dryer section in particular is important in order that the speed difference of the web between the press section and the pre-dryer section should remain as low as possible. Efficient drying is achieved and the speed difference is minimized in the blowing dryer portion situated at the beginning of the pre-dryer section. The blowing drying also speeds up grade change because the regulation of the

temperature of the blowing drying units is quick. The pre-dryer section can start from a planar dryer portion that applies blowing drying, which is followed by a cylinder drying portion. In the cylinder drying groups it is also possible to use suction cylinders which are placed in the basement spaces, which have a large diameter and in connection with which impingement units are placed for drying the web running on the outer surface of the suction cylinder. Impingement drying also enables more efficient control of the moisture profile as compared with mere cylinder drying. *PCT patent application FI98/00945* discloses a dryer section that applies impingement and which is marketed under the trademark *OptiDry™*. The pre-dryer section can also be provided with steaming or moisturizing devices known in themselves to allow curl of the paper web to be controlled and regulated.

After the pre-dryer section the web is passed to a pre-calender, which can be formed of a soft calender or an extended nip calender. The extended nip calender can be a shoe calender or a belt calender. In a shoe calender, the extended nip is formed between a shoe roll and a hard surface thermo roll. The shoe roll comprises a stationary support structure and an elastic belt shell disposed rotatably around it. The belt shell is loaded against the thermo roll by means of a loading shoe which is supported on the support structure of the shoe roll and which forms an extended nip with the thermo roll. The belt calender can be formed by a thermo roll, a belt loop and a backup roll, which can be either a hard surface or a soft surface roll. The belt runs over the backup roll and guide/tension rolls. In this kind of belt calender, the extended nip is formed between the belt and the hot thermo roll, in which connection, for example, a metal belt can be used. One such belt calender is disclosed in *US patent 5,483,873*. As the pre-calender it is also possible to use a one-nip calender if both calendering backup surfaces are heatable. *FI patent application 971342* discloses one belt calender application in which the web runs in a nip between two elastic surface rolls between metal belts running around said rolls. If both metal belts are heated, a one-nip calender is provided in which both surfaces of the web can be subjected to the treatment of a

hot calendering backup surface. The pre-calender is, however, advantageously a two-nip or multi-nip calender in which both surfaces of the web can be subjected to the treatment of a thermo roll. One advantageous calender suitable for a pre-calender is the soft calender which is marketed under the trademark *OptiSoft™* in which a nip is formed between a roll provided with an elastic cover and a hard surface thermo roll. One *OptiSoft™* calender application is disclosed in *FI patent application 992214*. Another advantageous calender suitable for a pre-calender is the shoe calender which is marketed under the trademark *OptiDwell™* and of which one application is disclosed in *US patent 6,158,333*.

The pre-calender is followed by coating of the web, by which the surface structure of the base paper is evened out. Coating can be performed by applying a film coating method or a non-contact coating method. The non-contact coating methods include, among other things, a spray coating method, a curtain coating method and a dry coating method. *FI patent 97247* discloses a spray coating method marketed under the trademark *OptiSpray™*. *FI patent application 991863* describes a curtain coating method. It is common to these coating methods that the coating layer becomes substantially equally thick. The coating layer conforms to the surface profile of the base paper, with the result that an uneven web surface causes an uneven coating surface. Coating is performed advantageously in a compact coating station, in which both surfaces of the web can be coated simultaneously. A film coating method is very suitable for such coating. The closed and smooth surface of the web achieved by pre-calendering provides good conditions for coating. In that connection, it is preferable to use a profiling coating device, which can be controlled automatically based on profile measurements. This ensures a good cross-direction profile for the coated web and a uniform quality for the coated paper. As an applicator device it is possible to use a two-side film coating device which is marketed under the trademark *OptiSizer™* and in which both surfaces of the web can be treated simultaneously with a starch or pigment suspension. When needed, very light coating can be performed by this kind of applicator device, in which connection the basis weight of coating is at

least about 2 g/m^2/page. One coating device of this type is described in *FI patent 81734*.

The coating station is followed by an after-dryer section which starts with a dryer portion applying contact-free drying. The contact-free drying is followed by a short cylinder group, by which the stabilizing of the running of the web, the draw and tension of the web are primarily affected at the same time as drying is continued. The cylinder group advantageously applies single-wire draw. In connection with contact-free drying, it is possible to apply the drying which is marketed under the trademark *TurnDry*™ and in which the paper web is dried, supported in a contact-free manner and turned by the same device, for example, by a combination of a turning device and an airborne web-dryer. This enables a quick grade change and, at the same time, stable running of the web is assured. One such drying method is described in *FI patent 98944*.

After that, there is on-line end calendering, the aim of which is primarily to improve the gloss of the coated web because the required smoothness of the web has already been achieved in the pre-calender. The two-sidedness associated with the roughness of the web has also been corrected on the pre-calender, so that it is not any more necessary to make so much correction in the end calender. As a result of this, end calendering can be made lighter. End calendering can be performed by a soft calender or a multi-nip calender. As a soft calender it is possible to use a calender marketed under the trademark *OptiSoft™* having a nip which is formed between a roll provided with an elastic cover and a hard surface thermo roll. One *OptiSoft™* calender application is disclosed in *FI patent application 992214*. The calender described in *FI patent 96334* and marketed under the trademark *OptiLoad*™ can be used as a multi-nip calender, the rolls of the roll stack in said calender being relieved such that there is the same linear load in each nip. By the multi-nip calender is here meant a calender which comprises at least three rolls in contact with one another such that two nips are formed between the rolls. The roll stack of the multi-nip calender can be located in a vertical plane

or the roll stack can form an angle with a vertical plane. The multi-nip calender can also be formed of several separate roll stacks mounted on the same frame or on different frames, so that each roll stack forms, in a way, a multi-nip calender of its own. A soft calender having 2-4 nips and a multi-nip calender having 4-7 nips provide the gloss and the smoothness required from the end product in the arrangement in accordance with the invention. In that connection, the surface temperature of the thermo rolls in the soft calender is at least 150 °C, the linear load is in a range of 50-500 kN/m, and the surface temperature of the thermo rolls in the multi-nip calender is at least 120 °C and the linear load is in a range of 150-600 kN/m. The moisture content of the web before end calendering is regulated to be in a range of 5-11 %, advantageously in a range of 5-9 %.

The paper machine ends in a reel-up, for example, a reel-up which is marketed under the trademark *OptiReel*™ and of which one application is described in *FI patent 91383*. This kind of reel-up allows the amount of bottom broke to be minimized and a high-quality reel to be achieved, so that further processing of the reel takes place without problems.

Appropriate automation and measurement devices are combined with the method and the paper machine for manufacturing LWC printing paper coated once in accordance with the invention, for example, for the purpose of determining and correcting longitudinal and cross-direction profiles of the web or for accomplishing a quick grade change. As a measurement device is used, for example, a cross beam having several sensors or scanners and, at the same time, it is possible to measure machine-direction variation, for example, by scanning devices.

In summary, it may be stated that high-quality LWC printing paper which is coated once can be produced efficiently by the paper machine according to the invention.

By using profiling devices, profile variations found in the web can be corrected in different parts of the manufacturing line. The basis weight can be profiled by regulating the consistency of the headbox. In the press section, a steam box can be used for increasing and profiling the solids content. Blowing drying enables the drying to be profiled and in the dryer section it is also possible to use a moisturizing device for profiling the solids content. Surface size/coating amount can be profiled by coaters of the *OptiSizer ™*type.

In connection with the invention, it is also possible to use arrangements suitable for control of curl of a paper web, these arrangements being described in *FI patent applications 906216, 950434, 964830 and 972080.*

In the following, the invention will be described with reference to the figures in the appended drawings, to the details of which the invention is, however, not meant to be exclusively confined.

Figure 1 shows a forming section and a press section of a paper machine in accordance with the invention.

Figure 2 shows the upstream end of a pre-dryer section.

Figure 3 shows the downstream end of the pre-dryer section.

Figure 4 shows a pre-calender, a coating station and an after-dryer section.

Figure 5 shows an end calender and a reel-up.

Figure 6 shows the PPS-s10 roughness of base paper as a function of bulk for an uncalendered base paper, a conventionally pre-calendered base paper and a base paper subjected to reinforced pre-calendering.

Figure 7 shows the Cobb-Unger oil absorption of base paper as a function of bulk for an uncalendered base paper, a conventionally pre-calendered base paper and a base paper subjected to reinforced pre-calendering.

Figure 8 shows the PPS-s10 roughness of coated paper as a function of bulk for an LWCO printing paper which has been pre-calendered in accordance with the state of the art and coated by a blade coating method and a film coating method, and for an LWCR printing paper which has been coated by a blade coating method.

Figure 9 shows, as a function of bulk, the roughness of LWCO printing paper which has been film-coated once and pre-calendered in accordance with the state of the art and the roughness of an LWCO printing paper which has been film-coated once and subjected to reinforced pre-calendering.

Figure 10 shows, as a function of bulk, the roughness of an LWCR printing paper which has been film coated once and pre-calendered in accordance with the state of the art and the roughness of an LWCR printing paper which has been film coated once and subjected to reinforced pre-calendering.

The paper machine shown in Figs. 1-5 comprises, in the running direction of a web W, a headbox 100, a gap former 200, a press section 300, a pre-dryer section 400, a pre-calender 500, a coating station 600, an after-dryer section 700, an end calender 800, and a reel-up 900.

Fig. 1 shows the upstream end of the paper machine, i.e. the headbox 100, the gap former 200 and the press section 300. The headbox 100 is advantageously a dilution headbox and it may also include layering of fibres and/or fillers and/or fines and/or additives. The gap former 200 comprises a first wire loop 201 and a second wire loop 202, between which loops a substantially vertical forming zone is formed. Stock is fed from the headbox 100 into a gap formed by the first 201 and the second 202 wire loop between a forming suction roll 203 and a breast roll

204. In the forming zone, a first dewatering unit 206 is arranged inside the first wire loop 201 and a second dewatering unit 207 comprising loading dewatering members is arranged inside the second wire loop 202. Water is removed from the web and the formation of the web that is being formed is improved by means of the dewatering units 206, 207. At the end of the forming zone, the running direction of the formed web W is turned by means of the vacuum of a suction roll 205 placed inside the second wire loop 202, by the suction of which vacuum the web W is separated from the first wire 201 and caused to adhere to the second wire 202. After that, the web W is transferred on support of the second wire 202 to a pick-up point P, at which the web W is separated from the second wire 202 by a pick-up suction roll 303 and transferred on support of a first press felt 301, i.e. a pick-up felt, to the press section 300.

In the press section 300, the web W is passed between the first upper press felt 301 and a second lower press felt 302, where the web W runs to a first press nip NP1. The first press nip NP1 is an extended nip formed by a lower shoe roll 306 provided with a loading shoe and a belt shell and by an upper recessed surface counter roll 305. After the first press nip NP1, the web W is separated from the first press felt 301 at a first transfer point S1 by means of the vacuum of a first transfer suction roll 304 situated inside the second press felt loop 302 and caused to adhere to the second press felt 302. After that, the web W is passed on support of the second press felt 302 to a second transfer point S2, at which the web is separated from the second press felt 302 by means of the vacuum of a second transfer suction roll 313 situated inside a third press felt loop 311 and caused to adhere to the third press felt 311. After that, the web W is passed on support of the third press felt 311 to a second press nip N2. The web W runs in the second press nip N2 between the third upper press felt 311 and a fourth lower press felt 312. The second press nip NP2 is an extended nip, which is formed by an upper shoe roll 316 provided with a loading shoe and a belt shell and by a lower recessed surface counter roll 315. After the second press nip NP2, the web W is separated from the third press felt 311 and transferred on support of the fourth press felt 312

to a third transfer point S3, at which the web W is separated from the fourth press felt 312 by means of the vacuum of a fourth transfer suction roll 410 situated inside a drying wire loop 419 of a first drying group R1 in the pre-dryer section 400. After that, the web W is transferred on support of said drying wire 419 to the pre-dryer section 400.

Here it is also possible to use a press section in which one of the press felts 311, 312 of the second press nip NP2 is replaced with a substantially non-water-receiving transfer belt. By the transfer belt it can be ensured that, after the second press nip NP2, the web W follows the transfer belt on whose surface the web W is passed to the pre-dryer section 400.

Fig. 2 shows the upstream end of the pre-dryer section 400 illustrating first three drying groups R1, R2, R3 that apply single-wire draw. The first group R1 is a downwards open drying group R1 in which heated drying cylinders 411, 413, 413 are above and reversing suction rolls 414, 415 are below.

The web W is brought to the pre-dryer section 400 on support of the drying wire 419 of the first drying group R1 aided by the vacuum of a suction box 416 disposed inside said drying wire loop 419. After that, the web W runs along a meandering path between the drying cylinders 411, 412, 413 and the reversing suction rolls 414, 415. Above the first reversing suction roll 414 there is a runnability component 417, which ensures the running of the web W in the portion between the first reversing suction roll 414 and the upper drying cylinders 411, 412.

From the last drying cylinder 413 of the first drying group R1 the web W is passed in a nip between said drying cylinder 413 and a drying wire 429 of the second drying group R2 onto the drying wire 429 of the second drying group R2 and to a first reversing suction roll 424 of the second drying group R2. From said reversing suction roll 424 the web W is passed to a first drying cylinder 421 of the

second drying group R2 and therefrom further to a large-diameter impingement and/or through drying cylinder 420, preferably having a diameter of over 4 m, situated below the floor level of the paper machine hall. The impingement units of the impingement drying cylinder 420 are designated by the reference numerals 420a and 420b. From the impingement drying cylinder 420 the web W is passed to a second drying cylinder 422 of the second drying group R2 and therefrom further in a meandering fashion over a second reversing suction roll 425 of the second drying group R2 to the last drying cylinder 423 of the second drying group R2. Runnability components 426, 427 are disposed on the reversing suction rolls 424, 425 of the second drying group R2. The impingement and/or through drying cylinder 420 placed below the floor level of the paper machine hall provides a long drying distance for the web in relation to the machine direction advance of the web.

From the last drying cylinder 423 of the second drying group R2, the web W passes in a nip between said drying cylinder 423 and a drying wire 439 of the third drying group R3 onto the drying wire 439 of the third drying group R3 and to a first reversing suction roll 434 of the third drying group R3. After that, the web W runs in a meandering fashion between drying cylinders 431, 432, 433 and reversing suction rolls 435, 436 of the third drying group R3. A runnability component 437 is disposed on the first reversing suction roll 434 of the third drying group R3.

Fig. 3 shows the downstream end of the pre-dryer section 400 illustrating latter four drying groups R4-R7. The fourth R4 and the sixth R6 drying group correspond in structure to the second drying group R2. The fifth R5 and the seventh R7 drying group in turn correspond in structure to the third drying group R3. The pre-dryer section 400 thus comprises in total seven drying groups R1-R7. The second R2, the fourth R4 and the sixth R6 drying group are provided with impingement cylinders 420, 440, 460 situated below the floor level and with associated impingement units 420a, 420b; 440a, 440B; 460a, 460b.

The run of the web W is closed and supported from the beginning of the forming section 200 to the end of the pre-dryer section 400.

Fig. 4 shows the pre-calender 500, the coating station 600 and the after-dryer section 700 situated after the pre-dryer section 400.

From the last drying cylinder 473 of the last i.e. the seventh drying group R7 in the pre-dryer section 400, the web W is passed as an open draw via a first measurement device 490 to the pre-calender 500. The cross profile of the web W is measured in the first measurement device 490 in order that the variations found in it might be taken into account in pre-calendering. The variations in the cross profile of the web are sought to be equalized by performing profiled pre-calendering.

The pre-calender 500 may be a soft calender, a shoe calender or a belt calender. The nip of the soft calender is formed between a thermo roll having a hard surface and a backup roll having an elastic surface. The nip of the shoe calender is formed between a thermo roll having a hard surface and a shoe roll serving as a backup roll. The nip of the belt calender can be formed between a thermo roll having a hard surface and a metal belt running around a backup roll having an elastic surface or between two rolls having a elastic surface and metal belts running around the rolls. In the figure, the pre-calender 500 is a two-nip NE1, NE2 shoe calender, in which the first pre-calendering nip NE1 is formed by a lower first shoe roll 510 and an upper hard surface first thermo roll 511. The second pre-calendering nip NE2 is formed by an upper second shoe roll 520 and a lower hard surface second thermo roll 521. The upper surface of the web W is thus placed against the outer surface of the shell of the first thermo roll 511 in the first pre-calendering nip NE1 and the lower surface of the web W is placed against the outer surface of the shell of the second thermo roll 521 in the second pre-calendering nip NE2.

In connection with the pre-calender 500, there is also shown a first moisturizing device 512 of the web W, which is situated before the first pre-calendering nip NE1 on the side of the thermo roll 511 of the first pre-calendering nip NE1, and a second moisturizing device 522 of the web W, which is situated between the first pre-calendering nip NE1 and the second pre-calendering nip NE2 on the side of the thermo roll 521 of the second pre-calendering nip NE2. When needed, the moisture content of the web W can be regulated by the moisturizing devices 512, 522 so as to be suitable separately for each pre-calendering nip NE1, NE2. As the moisturizing devices 512, 522 it is possible to use steam moisturizing devices or water moisturizing devices known in themselves. The first moisturizing device 512 is necessary only in the cases in which the web W has been dried too dry in the pre-dryer section 400, in which connection the moisture content of the web W must be raised before pre-calendering. This is, of course, not desirable but the web W should be dried already in the pre-dryer section 400 to a correct solids content appropriate for pre-calendering. If there is no need to enhance the calendering effect of the second pre-calendering nip NE2, the second moisturizing device 522 can also be omitted. Moisturizing can also be arranged such that a moisturizing device 512, 512a is arranged on both sides of the web W before the first pre-calendering nip NE1 of the pre-calender 500 and/or such that a moisturizing device 522, 522a is arranged on both sides of the web W before the second pre-calendering nip NE2 of the pre-calender 500.

The moisturizing device 512, 512a is arranged at a suitable distance before the nip of the pre-calender such that the time of action of water before the nip is in a range of 0.05-0.5 s. The aim of an appropriately selected time of action is to cause both surfaces of the web to be moistened while the middle part of the web remains substantially non-moistened. In a two-nip calender, in which the web runs only a short distance between the nips, the web can be guided, when needed, to an additional loop between the nips in order that moisturizing shall have a sufficiently long time of action. Another possibility is that moisturizing is

performed only before the first nip of the pre-calender. In moisturizing, water is applied to the web in an amount of 1-4 g/m^2/side in order to achieve a desired moisture content. The initial moisture of the web, the temperatures of the thermo rolls of the pre-calender and the linear loads of the pre-calender determine the need for moisturizing.

After the pre-calender 500, the web W is passed via a second measurement device 590 to the coating station 600. The coating station 600 is a coating station 600 which applies roll application 611,612 and is based on film transfer and in which both surfaces of the web W are surface-sized/pigmented simultaneously. This kind of coating station is very efficient and it becomes relatively short in the machine direction. The second measurement device 590 measures the cross profile of the web W in order that the variations found in it might be taken into account in coating. The variations in the cross profile of the web are sought to be equalized by performing profiled coating.

After the coating station 600, the web W is passed to the after-dryer section 700. The after-dryer section 700 is mainly formed of a portion 710 applying contact-free drying and of a short cylinder group 720 applying single-wire draw. The portion 710 applying contact-free drying comprises an airborne web-dryer 711, a contact-free turning device 712 for the web W, and an infrared drying unit 713. The cylinder group 720 comprises a drying wire 729, heated drying cylinders 721, 722 and a reversing suction roll 723 between them. Between the portion 710 applying contact-free drying and the cylinder group 720, the web W is passed to a third measurement device 790. The third measurement device 790 measures the profile of the web W in order that the variations found in it might be taken into account in end calendering. The variations in the cross profile of the web are sought to be equalized by performing profiled end calendering.

Fig. 5 shows the end calender 800 and the reel-up 900.

From the last drying cylinder 722 of the cylinder drying group 720 of the after-dryer section 700, the web W is passed to the end calender 800, which is formed of a two-nip soft calender. A first calendering nip N1 is formed between a lower roll 810 having an elastic surface and an upper thermo roll 811 having a hard surface, and a second calendering nip N2 is formed between an upper roll 820 having an elastic surface and a lower thermo roll 821 having a hard surface. As the end calender 800 it is also possible to use a soft calender having 4 nips or a multi-nip calender having 4-7 nips. In the end calender 800, the gloss of the surfaces of the web W is mainly increased. From the last calendering nip N2 of the end calender 800, the web W is passed to the reel-up 900 in which machine reels 910 are made out of the web.

Fig. 6 shows the PPS-s10 roughness of base paper as a function of bulk. The filled squares represent the values measured from an uncalendered base paper, in which connection PPS-s10 roughness is in a range of 6.2-7.1 μm and bulk is in a range of 1.95-2.21 cm^3/g. The unfilled diamonds represent the values measured from a base paper pre-calendered by a one-nip machine calender in accordance with the state of the art, in which connection PPS-s10 roughness is in a range of 4.0-5.6 μm and bulk is in a range of 1.7-1.9 cm^3/g. The filled circles represent the values measured from a base paper subjected to reinforced pre-calendering on a two-nip soft calender, in which connection PPS-s10 roughness is in a range of 2.2-3.4 μm and bulk is in a range of 1.22-1.52 cm^3/g. The filled triangles represent the values measured from a base paper subjected to reinforced pre-calendering on a four-nip soft calender, in which connection PPS-s10 roughness is in a range of 2.1-2.8 μm and bulk is in a range of 1.22-1.32 cm^3/g. The unfilled squares represent the values measured from a base paper subjected to reinforced pre-calendering on a two-nip shoe calender, in which connection PPS-s10 roughness is in a range of 2.6-3.0 μm and bulk is in a range of 1.45-1.58 cm^3/g. The figure shows that values of below 3.5 μm in PPS-s10 roughness can be achieved with a base paper subjected to reinforced pre-calendering but, at the same time, some bulk is lost as compared with traditional pre-calendering.

Fig. 7 shows the Cobb-Unger oil absorption of base paper as a function of bulk. The filled squares represent the values measured from an uncalendered base paper, in which connection Cobb-Unger oil absorption is in a range of 16-28 g/m^2 and bulk is in a range of 1.95-2.21 cm^3/g. The unfilled diamonds represent the values measured from a base paper pre-calendered by a one-nip machine calender in accordance with the state of the art, in which connection Cobb-Unger oil absorption is in a range of 13-26 g/m^2 and bulk is in a range of 1.7-1.9 cm^3/g. The filled circles represent the values measured from a base paper subjected to reinforced pre-calendering on a two-nip soft calender, in which connection Cobb-Unger oil absorption is in a range of 6.5-14.5 g/m^2 and bulk is in a range of 1.22-1.48 cm^3/g. The filled triangles represent the values measured from a base paper subjected to reinforced pre-calendering on a four-nip soft calender, in which connection Cobb-Unger oil absorption is in a range of 8-13.5 g/m^2 and bulk is in a range of 1.22-1.32 cm^3/g. The unfilled squares represent the values measured from a base paper subjected to reinforced pre-calendering on a two-nip shoe calender, in which connection Cobb-Unger oil absorption is in a range of 12-15 g/m^2 and bulk is in a range of 1.45-1.59 cm^3/g. The figure shows that values of below 15 g/m^2 in Cobb-Unger oil absorption can be achieved with a base paper subjected to reinforced pre-calendering but, at the same time, some bulk is lost as compared with traditional pre-calendering.

It is seen from Figs. 6 and 7 that a sufficiently low PPS-s10 roughness and a sufficiently low Cobb-Unger oil absorption are achieved by a base paper which is subjected to reinforced pre-calendering in order that the base paper may be coated by applying a film coating method or a non-contact coating method for the manufacture of LWCR paper. The PPS-s10 roughness and Cobb-Unger oil absorption of the traditionally pre-calendered base paper require a blade coating method in order that paper meeting the quality requirements of LWCR might be manufactured.

Fig. 8 shows the PPS-s10 roughness of a printing paper coated once as a function of bulk for LWC paper. The base paper has been manufactured by pre-calendering in accordance with the state of the art on a one-nip machine calender, in which the temperature of the thermo roll was 60-100 °C and the linear load was 10-60 kN/m. The filled diamonds represent the values measured from an LWCO paper coated by a film coating method or a non-contact coating method, in which connection PPS-s10 roughness is in a range of 1.12-1.7 μm and bulk is in a range of 0.815-0.93 cm^3/g. The unfilled circles in turn represent the values measured from an LWCO paper coated by a blade coating method, in which connection PPS-s10 roughness is in a range of 0.9-1.57 μm and bulk is in a range of 0.81-1.0 cm^3/g. The unfilled triangles represent the values measured from an LWCR paper coated by a blade coating method, in which connection PPS-s10 roughness is in a range of 0.6-0.92 μm and bulk is in a range of 0.77-0.92 cm^3/g.

Fig. 9 shows, as a function of bulk, the roughness of LWCO printing paper coated once by a film coating method. The unfilled diamonds represent the values measured from a printing paper pre-calendered by a one-nip machine calender in accordance with the state of the art and film-coated once, in which connection PPS-s10 roughness is in a range of 1.7-1.75 μm and bulk is about 0.94 cm^3/g. The filled circles represent the values measured from a printing paper subjected to reinforced pre-calendering on a two-nip soft calender and film-coated once, in which connection PPS-s10 roughness is in a range of 1.21-1.39 μm and bulk is in a range of 0.9-0.95 cm^3/g. The results show that the PPS-s10 roughness of the LWCO printing paper manufactured in accordance with the invention is lower and its bulk is almost as high as the corresponding values of the LWCO printing paper manufactured by traditional pre-calendering.

Fig. 10 shows, as a function of bulk, the roughness of LWCR printing paper coated once by a film coating method. The unfilled diamonds represent the values measured from an LWCR printing paper pre-calendered by a one-nip machine calender in accordance with the state of the art and coated once by a blade coating

method, in which connection PPS-s10 roughness is in a range of 1.15-1.30 μm and bulk is in a range of 0.93-1.02 cm^3/g. The filled circles represent the values measured from an LWCR printing paper subjected to reinforced pre-calendering on a two-nip soft calender and film-coated once, in which connection PPS-s10 roughness is in a range of 0.85-1.15 μm and bulk is in a range of 0.875-1.02 cm^3/g. The filled triangles represent the values measured from an LWCR printing paper subjected to reinforced pre-calendering on a four-nip soft calender and film-coated once, in which connection PPS-s10 roughness is in a range of 0.97-1.29 μm and bulk is in a range of 0.92-1.00 cm^3/g. The unfilled squares represent the values measured from an LWCR printing paper subjected to reinforced pre-calendering on a two-nip shoe calender and film-coated once, in which connection PPS-s10 roughness is in a range of 1.1-1.21 μm and bulk is in a range of 0.92-0.97 cm^3/g. The results show that the PPS-s10 roughness and bulk of the LWCR printing paper manufactured in accordance with the invention are on the same level as the corresponding values of the LWCR printing paper manufactured by traditional pre-calendering.

The results according to the invention shown in Figs. 6-10 have been obtained with a base paper that contained at least 70 % mechanical pulp. In the pulp, 0-40 % of recycled fibres was also used, in which connection the mechanical fibres contained in the recycled fibres were included in the above-mentioned proportion of mechanical pulp. The proportion of chemical pulp was 0-30 %, which also included the chemical fibres contained in the recycled fibres. The pre-calendering in accordance with the state of the art was performed on a one-nip machine calender in which the temperature of the thermo roll was in a range of 60-100 °C and the linear load was in a range of 10-60 kN/m. In reinforced pre-calendering, a soft calender with 2-4 nips and a shoe calender with 2 nips were used. The temperature of the thermo rolls of the pre-calenders was in a range of 200-300 °C and the linear loads were in a range of 50-500 kN/m. The moisture content of the base paper before the pre-calender was 5-20 % and the running speeds used were in a range of 1500-2200 m/min. As the end calender, a soft calender with 2-4 nips

was used, in which connection the temperature of the thermo rolls was 200 °C, and a multi-nip calender with 5-7 nips, in which connection the temperature of the thermo rolls was 150 °C.

The results obtained by different pre-calendering arrangements are not necessarily quite directly comparable with one another. The largest trial series were performed on a two-nip soft calender, in which connection it has been possible to optimize better the pre-calendering and/or end calendering parameters affecting the end result.

The claims are presented in the following and the details of the invention may vary within the inventive idea defined by said claims and differ from the disclosure given above by way of example only.

Claims

1. A method for the manufacture of LWC printing paper coated once, comprising the following successive steps:

- feeding stock from a headbox (100) to a gap former (200), in which water is removed from a web (W) in two directions,
- passing the web (W) to a press section (300) which comprises at least one extended nip press and in which water is removed from the web (W) by pressing,
- passing the web (W) to a pre-dryer section (400), in which the web (W) is dried applying at least cylinder drying (R1-R7),
- passing the web (W) to a pre-calender (500), in which the web (W) is pre-calendered,
- passing the web (W) to a portion comprising at least one coating station (600) and one after-dryer section (700), in which the web (W) is coated on both sides applying a film coating method or a non-contact coating method and dried applying at least contact-free drying (710),
- passing the web (W) to an end calender (800), in which the web (W) is calendered, and
- passing the web (W) to a reel-up (900), in which the web (W) is reeled into machine reels (910),

characterized by

- passing the web (W) in the pre-calender (500) through at least one nip (NE1, NE2) such that both surfaces of the web (W) are in contact with a calendering backup surface having a surface temperature of at least 200 °C, advantageously at least 250 °C, in which connection the total length of the nip or nips of the pre-calender (500) is in a range of 15-600 mm and the linear load of each nip is in a range of 50-500 kN/m, advantageously in a range of 100-400 kN/m,

- regulating the moisture content of the web (W) before the first nip (NE1) of the pre-calender (500) in a range of 5-20 %, advantageously in a range of 6-15 %.

2. A method as claimed in claim 1, **characterized** in that the web is pre-calendered in a soft calender, in which it is passed through at least two nips (NE1, NE2), which are formed between a thermo roll (511, 521) and an elastic surface roll (510, 520) such that the thermo roll (511, 521) is situated in the nips alternately on the opposite sides of the web, in which connection the surface temperature of the thermo rolls (511, 521) is at least 200 °C, advantageously at least 250 °C, the total length of the nips (NE1, NE2) is in a range of 15-600 mm, advantageously in a range of 30-600 mm, the linear load of the nips (NE1, NE2) is in a range of 50-500 kN/m, advantageously in a range of 100-400 kN/m, and the moisture content of the web before the first nip (NE1) of the pre-calender (500) is in a range of 5-20 %, advantageously in a range of 6-15 %.

3. A method as claimed in claim 1, **characterized** in that the web (W) is pre-calendered in a shoe calender, in which it is passed through at least two nips (NE1, NE2), which are formed between a shoe roll (510, 520) and a hard surface thermo roll (511, 521) such that the thermo roll (511, 521) is situated in the nips (NE1, NE2) alternately on the opposite sides of the web, in which connection the surface temperature of the thermo rolls (511, 521) is at least 200 °C, advantageously at least 250 °C, the total length of the nips (NE1, NE2) is in a range of 15-600 mm, advantageously in a range of 30-600 mm, the linear load of the nips (NE1, NE2) is in a range of 50-500 kN/m, advantageously in a range of 100-400 kN/m, and the moisture content of the web before the first nip (NE1) of the pre-calender (500) is in a range of 5-20 %, advantageously in a range of 6-15 %.

4. A method as claimed in claim 2 or 3, **characterized** in that at least that surface of the web (W) which will be against the thermo roll (511) in the first nip (NE1) is moisturized (512) before the first nip (NE1), whereby the effect of the temperature of the thermo roll (511) of the pre-calender on the surface of the web (W) is enhanced.

5. A method as claimed in claim 2 or 3, **characterized** in that at least that surface of the web (W) which will be against the thermo roll (521) in the second nip (NE2) is moisturized (522) between the first and the second nip (NE1, NE2), whereby the effect of the temperature of the thermo roll (521) of the second nip on the surface of the web (W) is enhanced.

6. A method as claimed in any one of claims 2 to 5, **characterized** in that the asymmetry of the porosity and roughness of the surfaces of the web (W) is equalized in the pre-calender (500) by two-sided calendering, in which the more porous surface of the web is densified more than the denser surface of the web by regulating the moisture content (512, 522) of the web and/or the temperature of the thermo rolls (511, 521) of the nips (NE1, NE2).

7. A method as claimed in claim 1, **characterized** in that the web (W) is pre-calendered in a belt calender having a nip which is formed between a thermo roll and a metal belt running over a backup roll having an elastic surface, in which connection the surface temperature of the thermo roll and the metal belt is at least 200 °C, advantageously at least 250 °C, the length of the nip is in a range of 15-600 mm, advantageously in a range of 30-600 mm, the linear load of the nip is in a range of 50-500 kN/m, advantageously in a range of 100-400 kN/m, and the moisture content of the web before the pre-calender (500) is in a range of 5-20 %, advantageously in a range of 10-20 %.

8. A method as claimed in claim 7, **characterized** in that both surfaces of the web (W) are moisturized (512, 512a) before the pre-calender (500), whereby

the effect of the temperature of the thermo roll and the hot metal belt of the nip on the surface of the web (W) is enhanced.

9. A method as claimed in any one of claims 1 to 8, **characterized** in that a dilution headbox is used as the headbox (100).

10. A method as claimed in claim 9, **characterized** in that as the headbox (100) is used a multi-layer dilution headbox in which fibres and/or additives and/or fillers are layered.

11. A method as claimed in any one of claims 1 to 10, **characterized** in that a gap former provided with a forming roll (203) and dewatering units (206, 207) is used as the gap former (200).

12. A method as claimed in any one of claims 1 to 11, **characterized** in that as the press section (300) is used a press section which is provided with two successive extended press nips (NP1, NP2) and in which the extended press nips are formed between a shoe roll (306, 316) provided with an elastic belt shell and a recessed surface counter roll (305, 315), in which connection the counter roll is in the first press nip (NP1) on one side of the web (W) and in the second press nip (NP2) on the opposite side of the web (W).

13. A method as claimed in claim 12, **characterized** in that the web (W) runs in both press nips (NP1, NP2) between two press felts (301, 302; 311, 312).

14. A method as claimed in any one of claims 1 to 13, **characterized** in that the web (W) is dried in the pre-dryer section (400) by cylinder drying groups (R1-R7) which apply single-wire draw and by impingement drying units (420, 420a, 420b; 440, 44a, 44b; 460, 460a, 460b) which are disposed in connection with the cylinder drying groups.

15. A method as claimed in any one of claims 1 to 14, **characterized** in that the web (W) is passed after the pre-dryer section (400) and before the pre-calender (500) to a first measurement device (490), in which the profile of the web (W) is measured.

16. A method as claimed in any one of claims 1 to 15, **characterized** in that the web (W) is passed after the pre-calender (500) and before the coating station (600) to a second measurement device (590), in which the profile of the web (W) is measured.

17. A method as claimed in any one of claims 1 to 16, **characterized** in that the web (W) is passed in the after-dryer section (700) after a portion (710) applying contact-free drying and before a portion (720) applying cylinder drying to a third measurement device (790), in which the profile of the web (W) is measured.

18. A method as claimed in any one of claims 1 to 17, **characterized** in that the profiling of the properties of the paper web (W) is controlled based on the profile measurements of the paper web (W).

19. A method as claimed in any one of claims 1 to 18, **characterized** in that, in the pre-dryer section (400), the drying of the web (W) is profiled by impingement units (420a, 420b; 440a, 440b; 460a, 460b) associated with impingement cylinders (420, 440, 460).

20. A method as claimed in any one of claims 1 to 19, **characterized** in that the web (W) is calendered in an end calender (800) which is formed of a soft calender having 2-4 nips (N1, N2), in which connection the surface temperature of the thermo rolls is at least 150 °C, the linear load of the nips is in a range of 50-500 kN/m and the moisture content of the web before the first

nip of the end calender (800) is in a range of 5-11 %, advantageously in a range of 5-9 %.

21. A method as claimed in any one of claims 1 to 19, **characterized** in that the web (W) is calendered in an end calender (800) which is formed of a multi-nip calender having 4-7 nips, in which connection the surface temperature of the thermo rolls is at least 120 °C, the linear load of the nips is in a range of 150-600 kN/m and the moisture content of the web before the first nip of the end calender (800) is in a range of 5-11 %, advantageously in a range of 5-9 %.

22. A paper machine for the manufacture of LWC printing paper coated once, comprising in the running direction of a web (W):

- a headbox (100) from which stock is fed to a former,
- a gap former (200) in which water is removed from the web (W) in two directions,
- a press section (300) which comprises at least one extended nip press,
- a pre-dryer section (400) in which the web (W) is dried applying at least cylinder drying (R1-R7),
- a pre-calender (500) in which the web (W) is pre-calendered,
- at least one portion which is formed of a coating station (600) and a subsequent after-dryer section (700) and in which the web (W) is coated on both sides applying a film coating method or a non-contact coating method and dried applying at least contact-free drying (710),
- an end calender (800) in which the web (W) is calendered, and
- a reel-up (900) in which the web (W) is reeled,

characterized in that

- the pre-calender (500) is a calender which is provided with at least one nip (NE1, NE2) and in which both surfaces of the web (W) are in contact with a calendering backup surface having a surface temperature of at least 200 °C, advantageously at least 250 °C, the total length of the nip or nips (NE1, NE2)

of the pre-calender is in a range of 15-600 mm, advantageously in a range of 30-600 mm, the linear load of the pre-calendering nip or nips is in a range of 50-500 kN/m, advantageously in a range of 100-400 kN/m, and the moisture content of the web before the first nip (NE1) of the pre-calender is in a range of 5-20 %, advantageously in a range of 6-15 %.

23. A paper machine as claimed in claim 22, **characterized** in that the pre-calender (500) is formed of a soft calender in which there are at least two nips (NE1, NE2) which are formed by an elastic surface roll (510, 520) and a hard surface thermo roll (511, 521), so that the thermo roll is situated in the nips (NE1, NE2) alternately on the opposite sides of the web, the surface temperature of the thermo rolls (511, 521) is at least 200 °C, advantageously at least 250 °C, the total length of the nips (NE1, NE2) is in a range of 15-600 mm, advantageously in a range of 30-600 mm, the linear load of the nips (NE1, NE2) is in a range of 50-500 kN/m, advantageously in a range of 100-400 kN/m, and the moisture content of the web before the first nip (NE1) of the pre-calender (500) is in a range of 5-20 %, advantageously in a range of 6-15 %.

24. A paper machine as claimed in claim 22, **characterized** in that the pre-calender (500) is formed of a shoe calender in which there are at least two nips (NE1, NE2) which are formed by a shoe roll (510, 520) and a hard surface thermo roll (511, 521), so that the thermo roll is situated in the nips (NE1, NE2) alternately on the opposite sides of the web, the surface temperature of the thermo rolls (511, 521) is at least 200 °C, advantageously at least 250 °C, the total length of the nips (NE1, NE2) is in a range of 15-600 mm, advantageously in a range of 30-600 mm, the linear load of the nips (NE1, NE2) is in a range of 50-500 kN/m, advantageously in a range of 100-400 kN/m, and the moisture content of the web before the first nip (NE1) of the pre-calender (500) is in a range of 5-20 %, advantageously in a range of 6-15 %.

25. A paper machine as claimed in claim 23 or 24, **characterized** in that the paper machine comprises a first moisturizing device (512) situated, in the running direction of the web (W), before the first nip (NE1) of the pre-calender (500) for moisturizing at least that surface of the web (W) which will be against the thermo roll (511) in the first nip (NE1), whereby the effect of the temperature of the thermo roll (511) of the first nip on the surface of the web (W) is enhanced.

26. A paper machine as claimed in claim 23 or 24, **characterized** in that the paper machine comprises a second moisturizing device (522) placed in connection with the run of the web (W) between the first and the second nip (NE1, NE2) of the pre-calender (500) for moisturizing at least that surface of the web (W) which will be against the thermo roll (521) in the second nip (NE2), whereby the effect of the temperature of the thermo roll (521) of the second nip on the surface of the web (W) is enhanced.

27. A paper machine as claimed in any one of claims 22 to 26, **characterized** in that the pre-calender (500) is two-sided, so that the asymmetry of the porosity and smoothness of the surfaces of the web (W) is equalized by densifying the more porous surface of the web more than the denser surface of the web by regulating the moisture content (512, 522) of the web and/or the temperature of the thermo rolls (511, 521) of the nips (NE1, NE2).

28. A paper machine as claimed in claim 22, **characterized** in that the pre-calender is formed of a belt calender having a nip which is formed between a thermo roll and a metal belt running over a backup roll having an elastic surface, in which connection the surface temperature of the thermo roll and the metal belt is at least 200 °C, advantageously at least 250 °C, the length of the nip is in a range of 15-600 mm, advantageously in a range of 30-600 mm, the linear load of the nip is in a range of 50-500 kN/m, advantageously in a

range of 100-400 kN/m, and the moisture content of the web before the pre-calender (500) is in a range of 5-20 %, advantageously in a range of 6-15 %.

29. A paper machine as claimed in claim 28, **characterized** in that the paper machine comprises moisturizing devices (512, 512a) which are situated, in the running direction of the web (W), before the pre-calender (500) and by which both surfaces of the web (W) are moisturized, whereby the effect of the temperature of the thermo roll and the hot metal belt of the nip on the surfaces of the web (W) is enhanced.

30. A paper machine as claimed in any one of claims 22 to 29, **characterized** in that the headbox (100) is a dilution headbox.

31. A paper machine as claimed in any one of claims 22 to 30, **characterized** in that the headbox (100) is a multi-layer headbox.

32. A paper machine as claimed in any one of claims 22 to 31, **characterized** in that the gap former (200) is a gap former provided with a forming suction roll (203) and with at least one blade loading unit (206).

33. A paper machine as claimed in any one of claims 22 to 32, **characterized** in that the press section (300) is a press section provided with two extended press nips (NP1, NP2), the extended press nips (NP1, NP2) being formed between a shoe roll (306, 316), which is provided with a belt shell and a loading shoe, and a recessed surface counter roll (305, 315).

34. A paper machine as claimed in claim 33, **characterized** in that each press nip (NP1, NP2) of the press section (200) is double-felted (301, 302; 311, 312).

35. A paper machine as claimed in any one of claims 22 to 34, **characterized** in that the pre-dryer section (400) comprises cylinder drying groups (R1-R7)

which apply single-wire draw and to which impingement drying cylinders (420, 440, 460) provided with impingement units (420a, 420b; 440a, 440b; 460a, 460b) are connected.

36. A paper machine as claimed in any one of claims 22 to 35, **characterized** in that the coating station (600) is a film coating station applying two-side roll application (611, 612).

37. A paper machine as claimed in any one of claims 22 to 36, **characterized** in that the after-dryer section (700) comprises a contact-free dryer portion (710), which is followed by one cylinder drying group (720).

38. A paper machine as claimed in any one of claims 22 to 37, **characterized** in that it comprises a first measurement device (490) which is placed on the run of the web between the pre-dryer section (400) and the pre-calender (500) and in which the profile of the web (W) is measured.

39. A paper machine as claimed in any one of claims 22 to 38, **characterized** in that it comprises a second measurement device (590) which is placed on the run of the web (W) between the pre-calender (500) and the coating station (600) and in which the profile of the web (W) is measured.

40. A paper machine as claimed in any one of claims 22 to 39, **characterized** in that it comprises a third measurement device (790) which is placed on the run of the web (W) between the portion (710) applying contact-free drying and the portion (720) applying cylinder drying in the after-dryer section (700) and in which the profile of the web (W) is measured.

41. A paper machine as claimed in any one of claims 22 to 40, **characterized** in that the end calender (800) is a soft calender having 2-4 nips (N1, N2).

42. A paper machine as claimed in any one of claims 22 to 40, **characterized** in that the end calender (800) is a multi-nip calender having 4-7 nips.

43. A base paper intended for LWC printing paper which is coated once, **characterized** in that the base paper comprises at least 70 % mechanical pulp, and that the PPS-s10 roughness of the base paper before coating is below 3.5 μm, advantageously below 3 μm, that the Cobb-Unger oil absorption of the base paper before coating is below 15 g/m^2, advantageously below 12 g/m^2, and that the bulk of the base paper before coating is over 1.0 cm^3/g, advantageously over 1.2 cm^3/g.

44. A base paper as claimed in claim 43, **characterized** in that the base paper is manufactured in accordance with the method as claimed in claim 1.

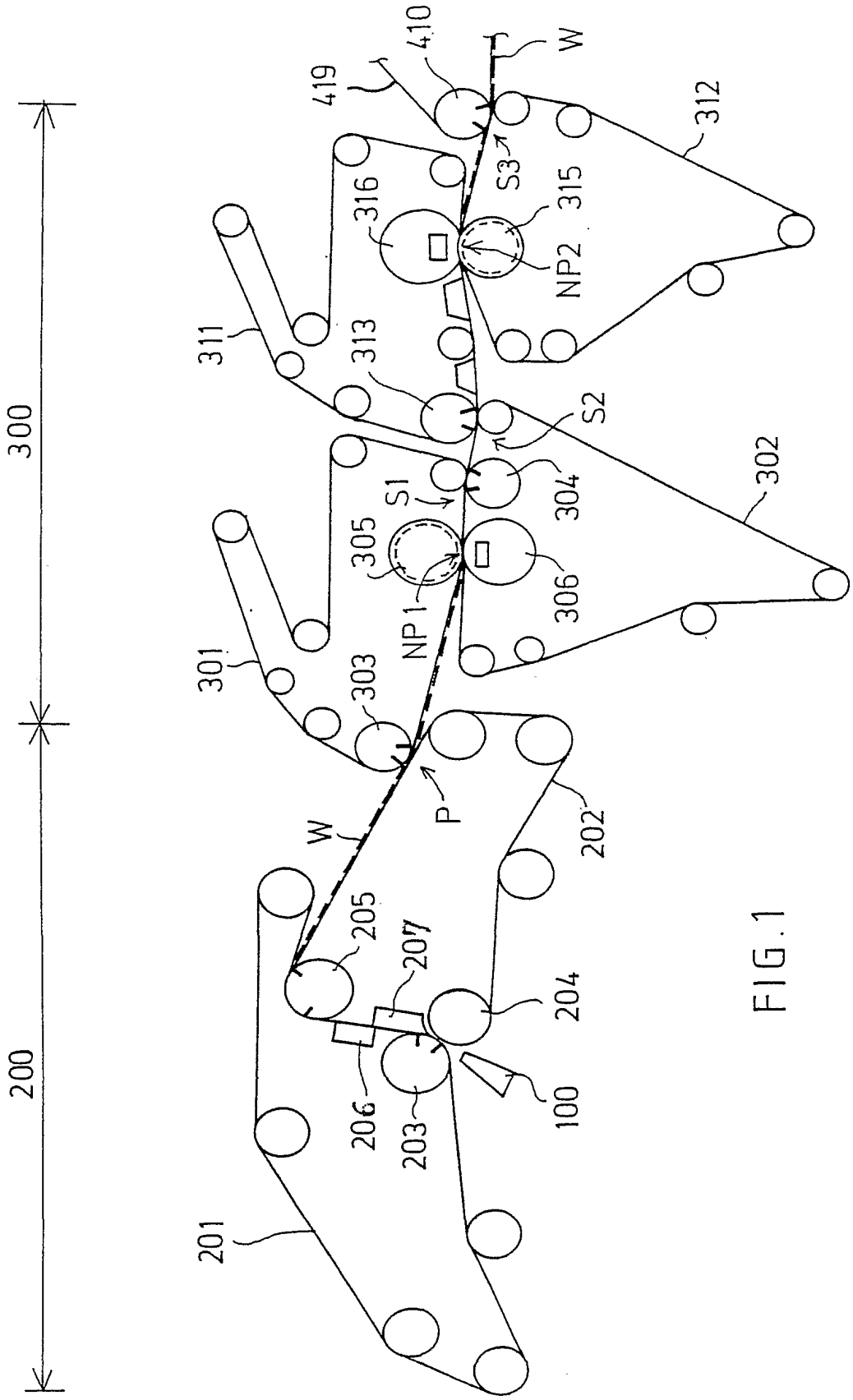
300
200
W
410
419
312
S3
316
315
NP2
311
313
S2
302
S1
304
305
306
NP1
301
303
P
202
W
205
207
204
206
203
100
201

FIG. 1

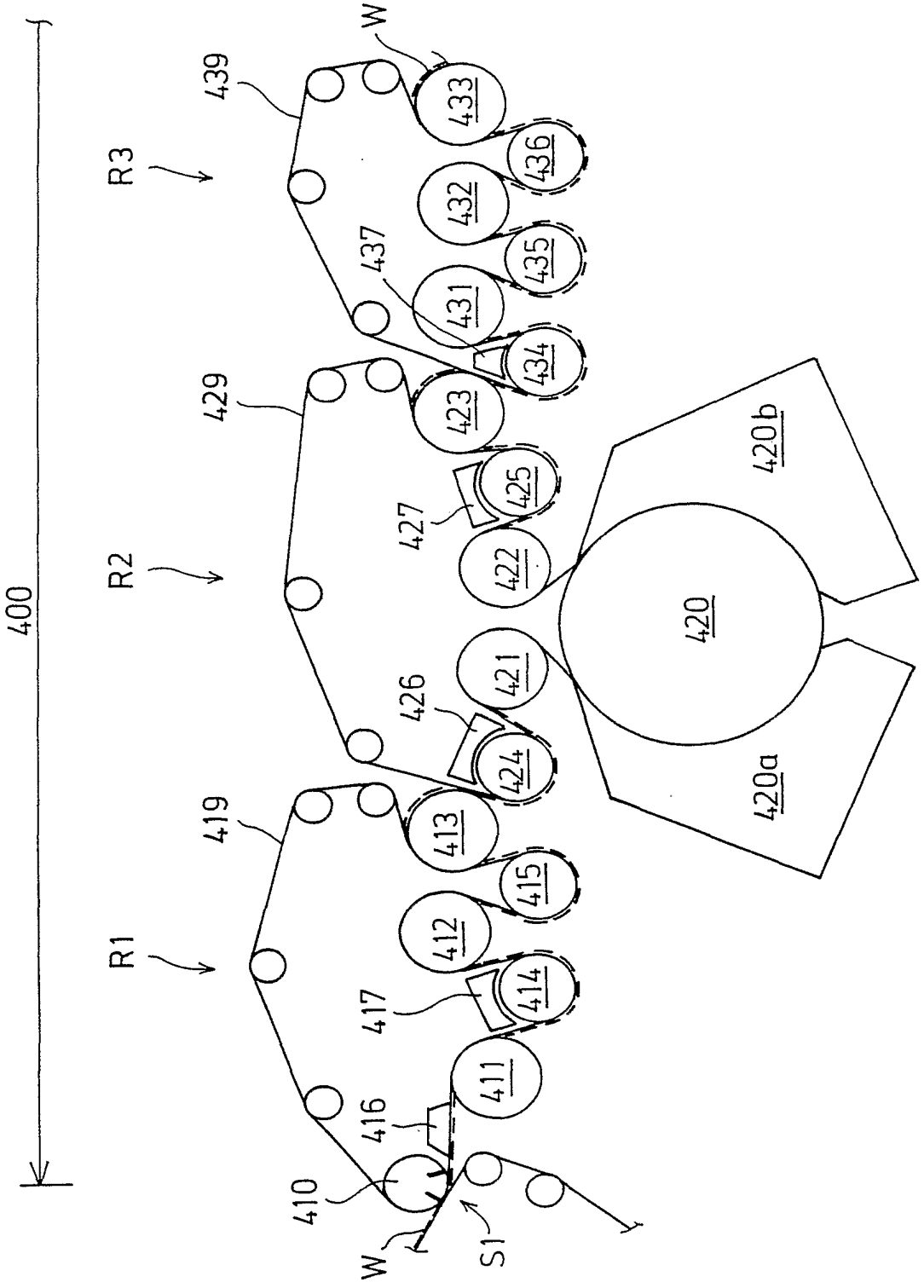
400
R1
R2
R3
410
411
412
413
414
415
416
417
419
420
420a
420b
421
422
423
424
425
426
427
429
431
432
433
434
435
436
437
439
W
W
S1

FIG.2

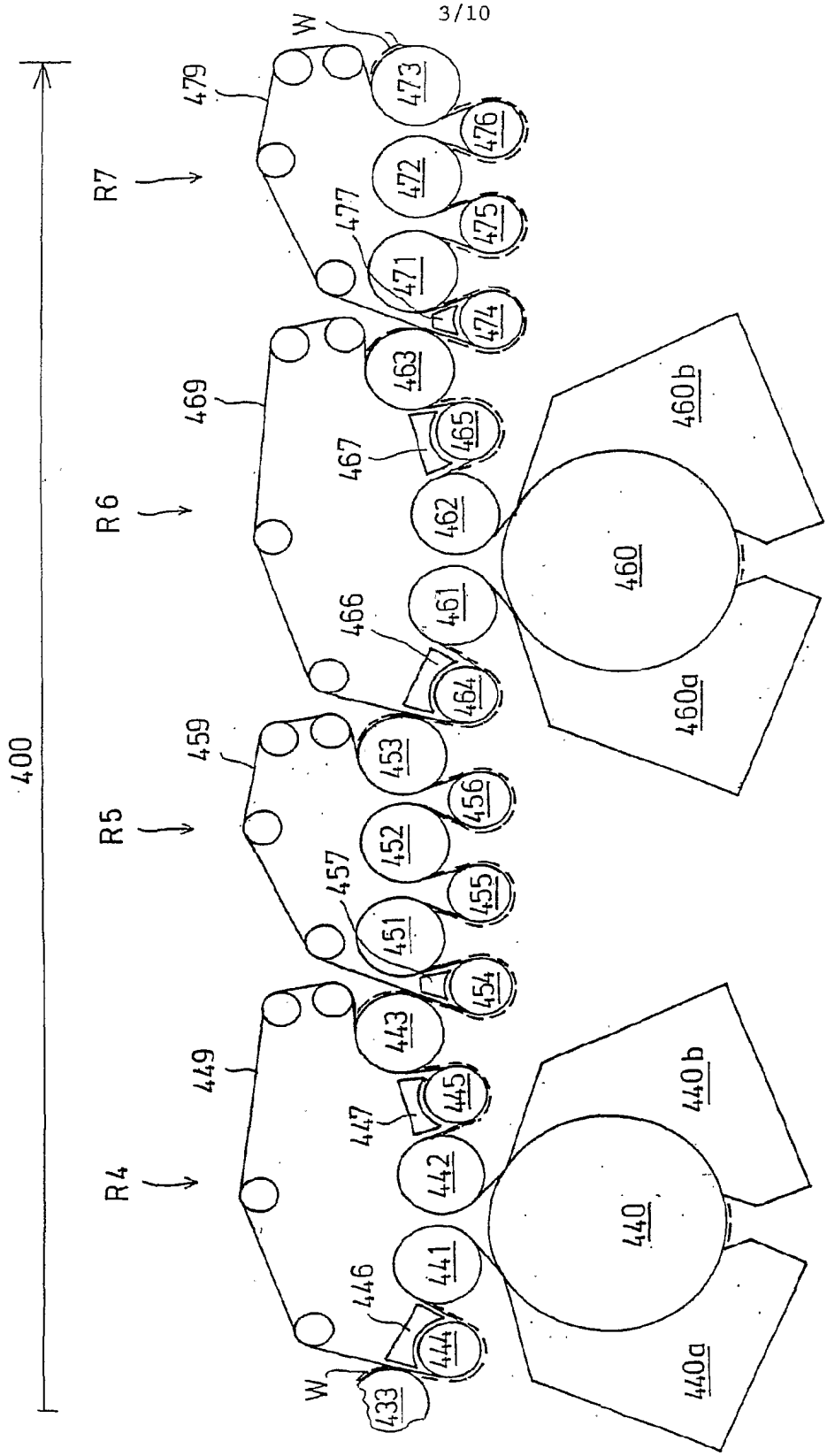
400
R4
R5
R6
R7
W
433
444
446
441
442
447
445
443
449
454
451
457
455
452
456
453
459
464
466
461
462
467
465
463
469
474
471
477
475
472
476
473
479
440
440a
440b
460
460a
460b

FIG. 3

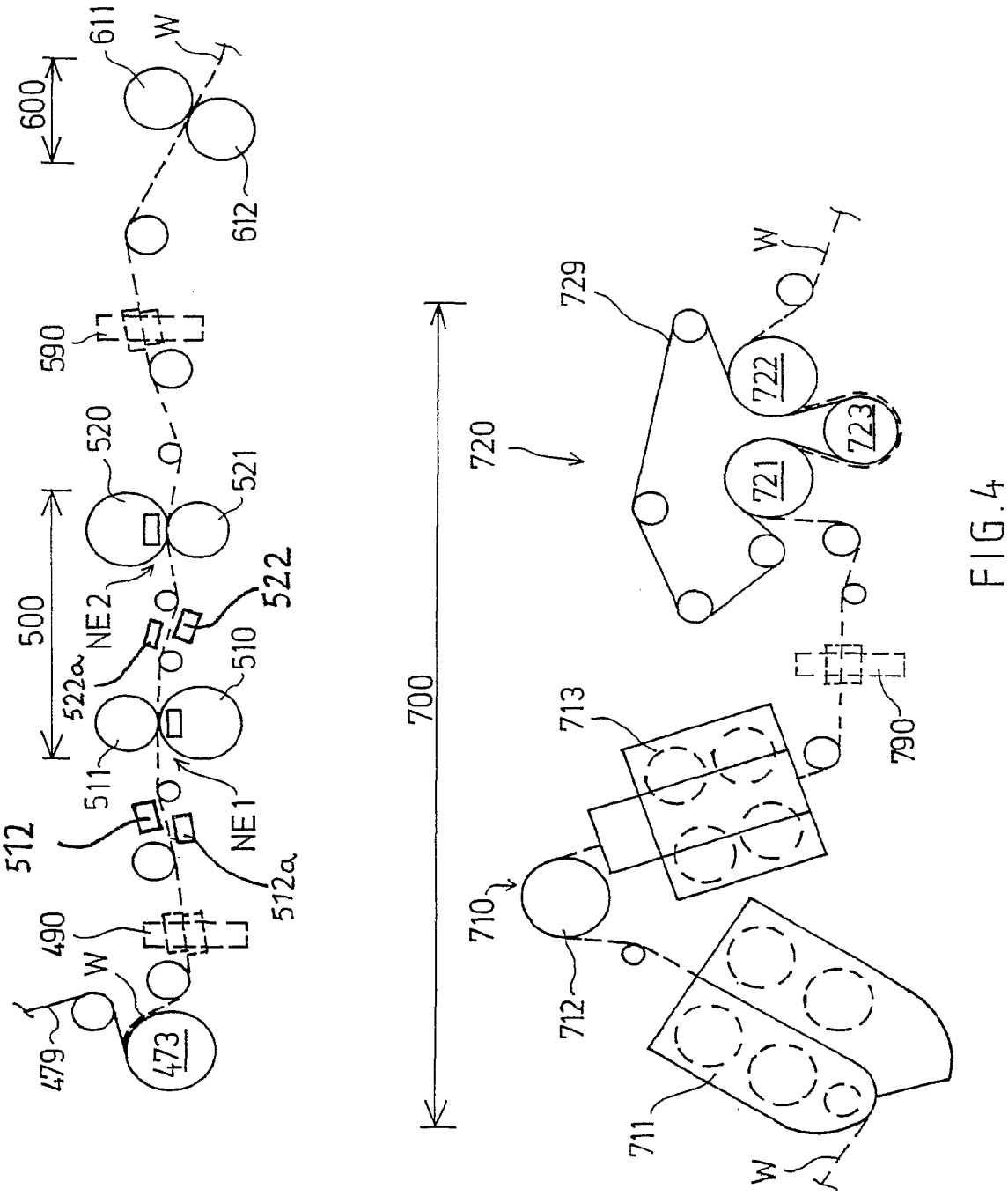
600
611
W
612
590
520
521
500
NE2
522a
522
510
511
512
NE1
512a
490
W
479
473
700
720
729
722
723
721
W
790
713
710
712
711
W

FIG. 4

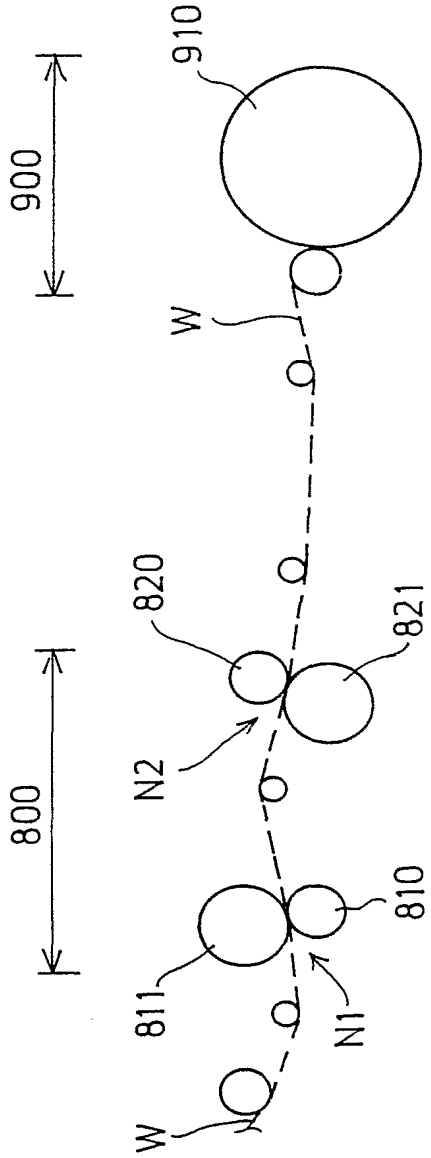

FIG.5

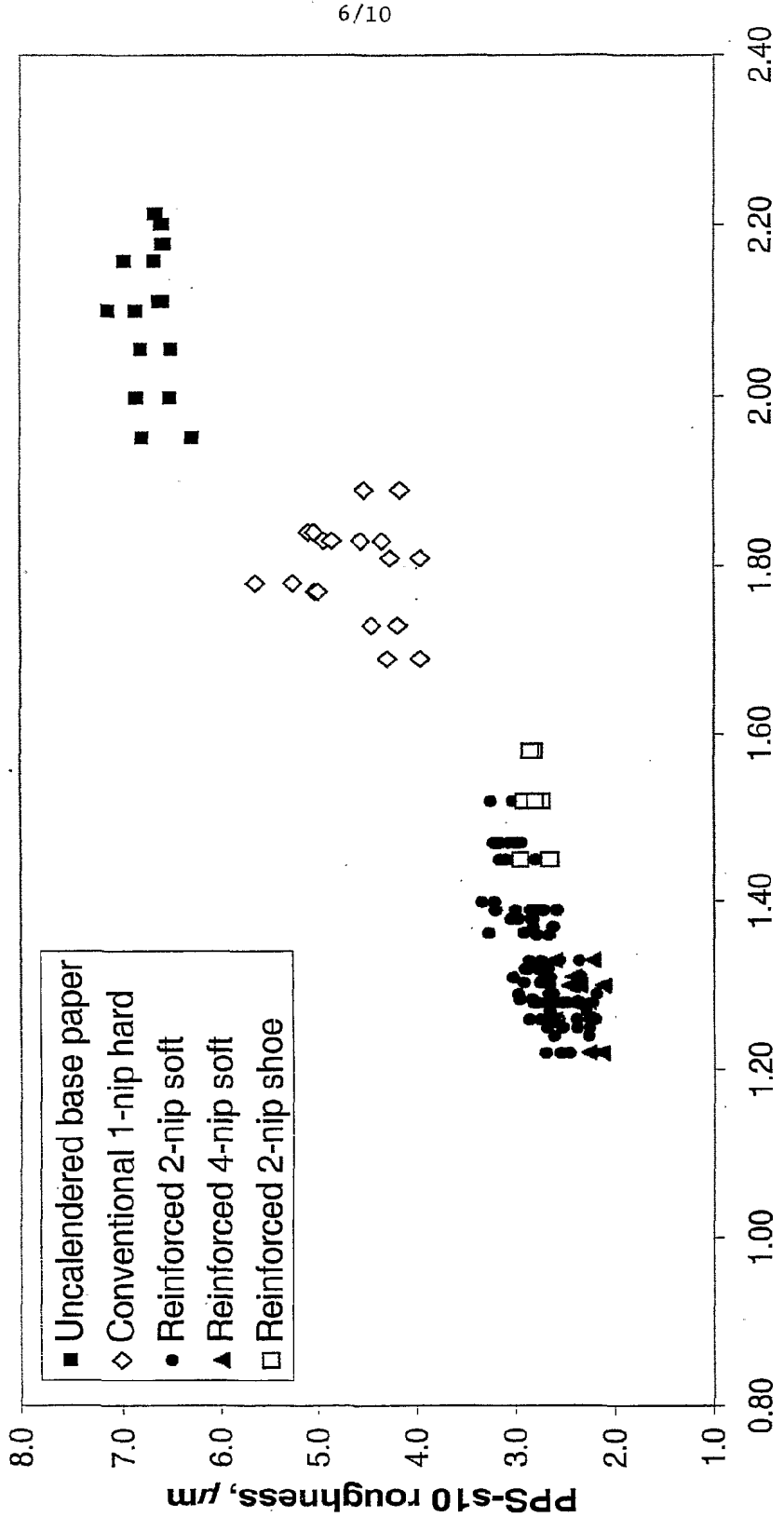
PPS-s10 roughness, µm
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2.20
2.40
Bulk, cm3/g
Uncalendered base paper
Conventional 1-nip hard
Reinforced 2-nip soft
Reinforced 4-nip soft
Reinforced 2-nip shoe

FIG. 6

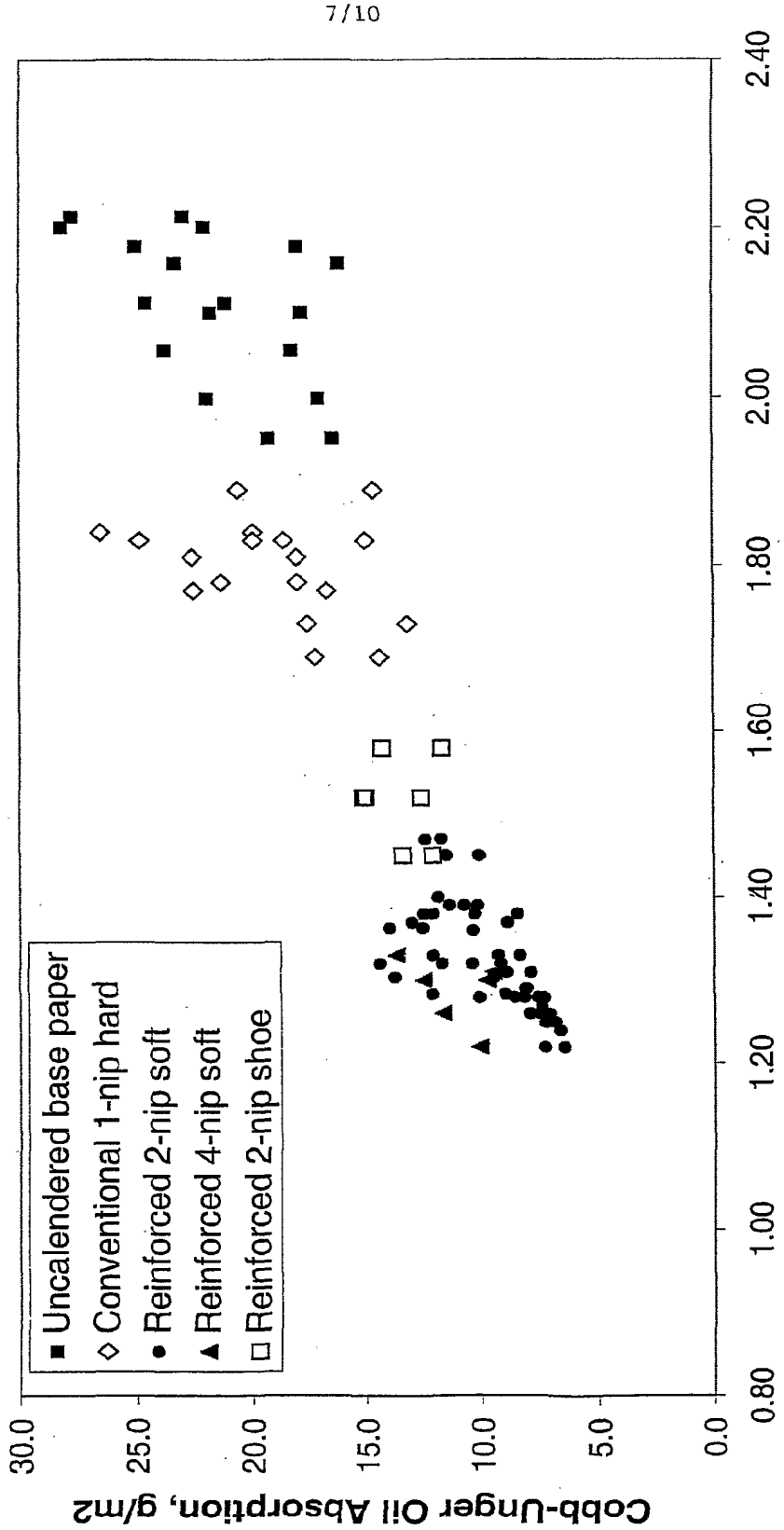
Cobb-Unger Oil Absorption, g/m2
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.80
1.00
1.20
1.40
1.60
1.80
2.00
2.20
2.40
Bulk, cm3/g
Uncalendered base paper
Conventional 1-nip hard
Reinforced 2-nip soft
Reinforced 4-nip soft
Reinforced 2-nip shoe

FIG. 7

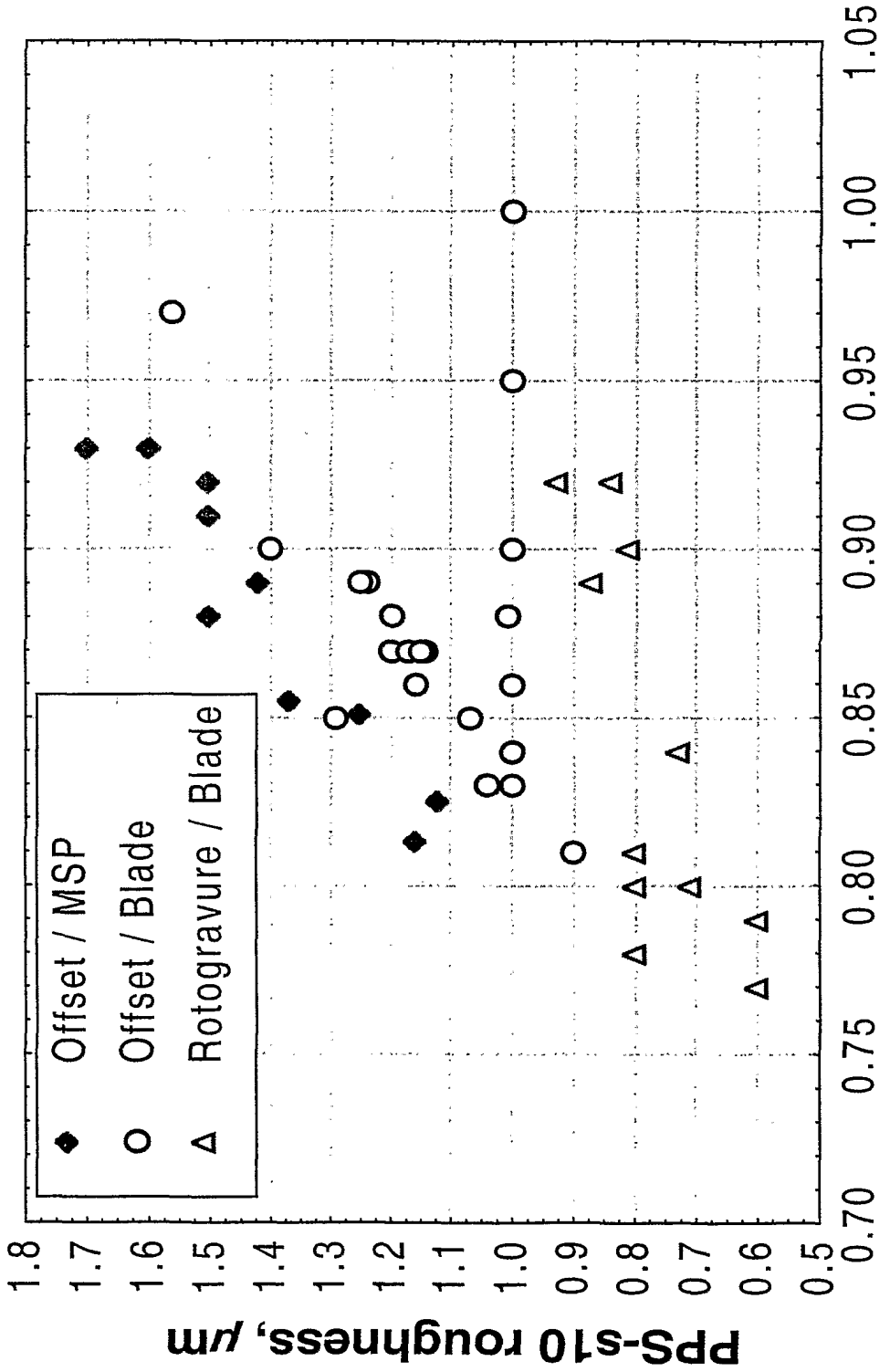
PPS-s10 roughness, µm
Bulk, cm3/g
Offset / MSP
Offset / Blade
Rotogravure / Blade
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.70
0.75
0.80
0.85
0.90
0.95
1.00
1.05

FIG. 8

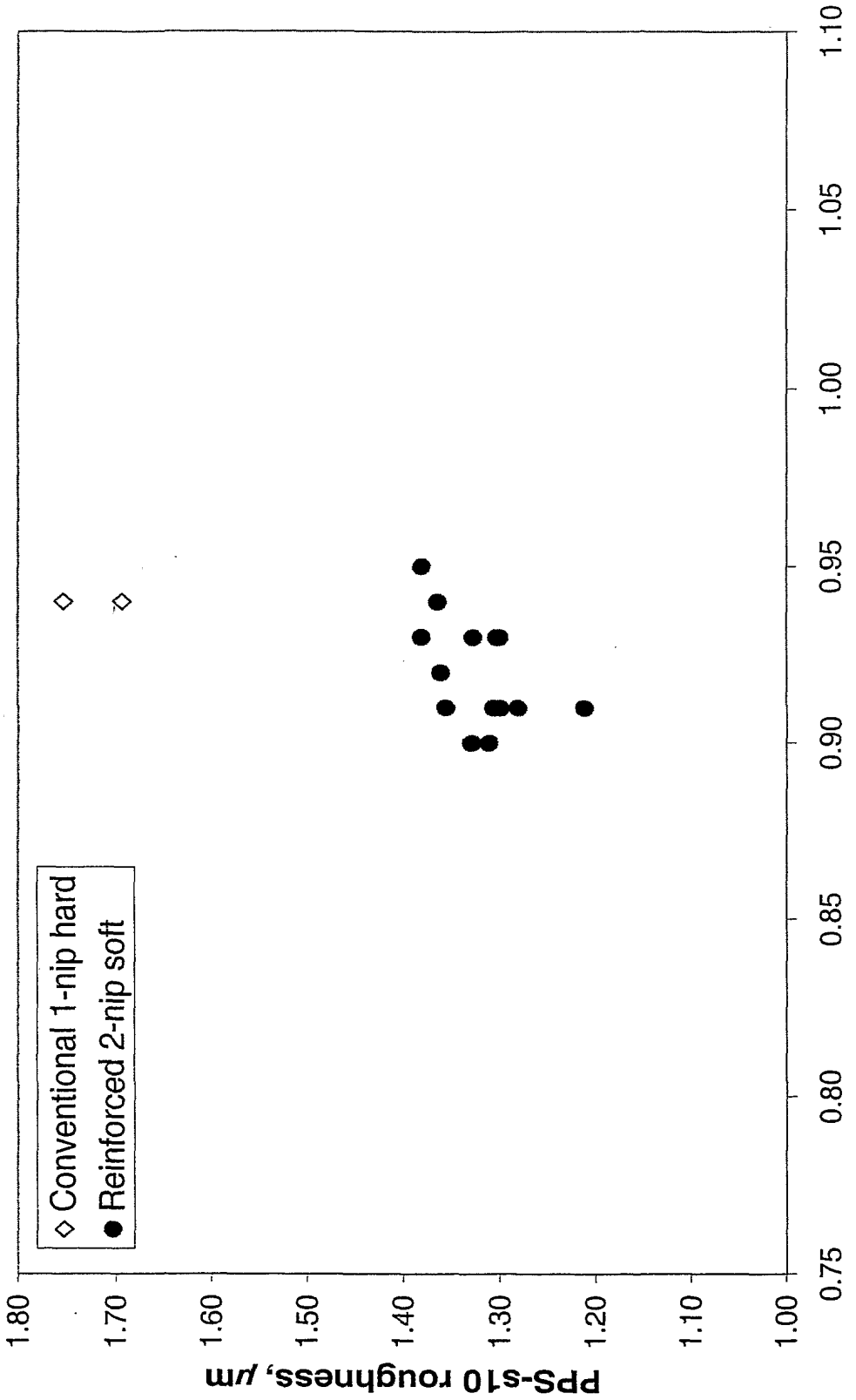
◇ Conventional 1-nip hard
● Reinforced 2-nip soft
PPS-s10 roughness, µm
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.75
0.80
0.85
0.90
0.95
1.00
1.05
1.10
Bulk, cm3/g

FIG. 9

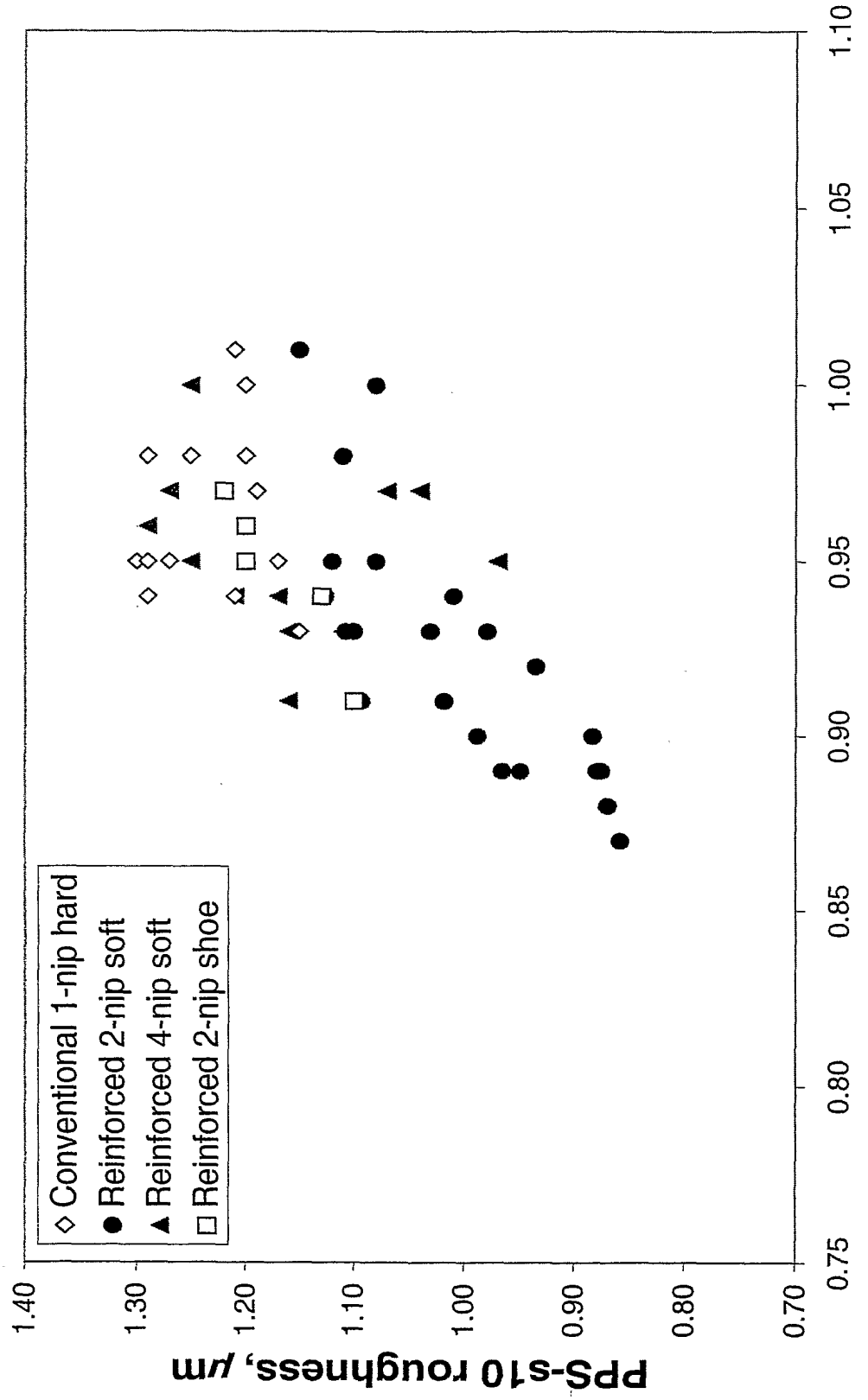
PPS-s10 roughness, µm
Bulk, cm³/g
◇ Conventional 1-nip hard
● Reinforced 2-nip soft
▲ Reinforced 4-nip soft
□ Reinforced 2-nip shoe
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.75
0.80
0.85
0.90
0.95
1.00
1.05
1.10

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 02/00528

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: D21F 9/00, D21F 11/00, D21H 19/00 // D21H 23/22, D21G 1/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: D21F, D21H, D21G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 0238858 A2 (METSO PAPER, INC.), 16 May 2002 (16.05.02), page 7, line 25 - page 8, line 29, abstract --	1-42
X	WO 0055424 A1 (VALMET CORPORATION), 21 Sept 2000 (21.09.00), page 6, line 10 - page 7, line 19, figure 1, abstract --	1-44
P,X	WO 0198585 A1 (METSO PAPER, INC.), 27 December 2001 (27.12.01), page 4, line 37 - page 5, line 7; page 7, line 34 - page 8, line 9; page 11, line 14 - line 34, abstract, table --	1-21,43-44

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 Sept 2002	27-09-2002
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Nina Bergström/ELY Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 02/00528

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 0070144 A1 (VALMET CORPORATION), 23 November 2000 (23.11.00), page 8, line 3 - line 12; page 9, line 1 - line 6, claim 18, abstract	22-42
A	--	1-21,43-44
A	WO 9964672 A1 (VALMET CORPORATION), 16 December 1999 (16.12.99), page 5, line 15 - line 31, abstract	1-43
	--	

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/09/02

International application No.
PCT/FI 02/00528

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0238858 A2	16/05/02	NONE	
WO 0055424 A1	21/09/00	AU 3294400 A	04/10/00
		DE 10084346 T	25/07/02
		FI 990558 A	13/09/00
WO 0198585 A1	27/12/01	AU 7257901 A	02/01/02
		FI 20001457 A	21/12/01
WO 0070144 A1	23/11/00	AU 4570900 A	05/12/00
		DE 10084571 T	16/05/02
		FI 991096 A	13/11/00
WO 9964672 A1	16/12/99	AU 4618499 A	30/12/99
		EP 1086272 A	28/03/01
		FI 981331 A	11/12/99
		US 6413371 B	02/07/02